Appendix A

Glossary of Field Abbreviations

Field	Definition
$Compl_{La}$	weighing (complexity) factor in reliability allocation for La
FIT	failure rate in units of 10^{-9}
FR	failure rate
L	(λ) failure rate (measure of reliability)
La	allocated failure rate
Lf	field failure rate (imported from FRACAS)
Lm	manually entered failure rate
Lp	predicted (calculated) failure rate
Ma	maintenance action
Mct	maintenance corrective time
MMH	mean maintenance man-hours
MTBCF	mean time between critical failures
MTBF	mean time between failures
MTTR	mean time to repair
NPRD	non-electronic part reliability data
PD	power dissipation
PTB	product tree building
R(t)	reliability as a function of time

Field	Definition
RBD	reliability block diagram
RG	reliability growth
RP	reliability prediction
RP component data	RP-related data influenced by the reliability prediction model ("Processor")
RTF	RAM Commander file format, used for importing data from ASCII files
S	ambiguity factor (average number of iterations required to correct a fault)
TAT	turn-around time
VSR	voltage stress ratio
Wm	weighing (complexity) factor for maintainability allocation
Xi	probability of fault isolation to N_i replaceable items

Appendix B

Tree Data Input Screens and Fields

The numbers in the column “Dialog boxes with this field” on the next page refer to the table below:

Dialog box name	Number
Tree Level Item Parameters	1
Tree General	2
Tree Operating (reliability)	3
Tree Nonoperating (reliability)	4
Tree Maintainability	5
Tree Miscellaneous	6

Tree Data Screens: fields and explanations

Field name	Description	Dialog boxes with this field	Values or field type
Family	Item family	2–4	--- ELECTRONIC MECHANICAL EL-MECH.
Item code	Item code	2–4	See list of item codes on page 600
Ref. Des.	Reference Designator	1–6	
Part name	Item part name	1–4	
Quantity	Quantity in current assembly	2–5	
Environment	Item environment	1, 3-4	See list of environment codes on page 603
Cur. ENV	Current environment (set to parent's environment if `---` in Environment field	1, 3-4	Set by RAM Commander
Method of Lp	If `user defined`, you must fill in the Method field	3–4	Default User defined
Method	Required if Method of Lp or Method of Mct are `user defined`	3–4	See list of prediction methods on page 601
(No prompt)	Source for failure rate	3–4	Calculated User defined From FRACAS Allocated

Field name	Description	Dialog boxes with this field	Values or field type
(No prompt)	Type of ambient temperature. If Fixed Temp, the item's temperature is equal to the value entered in the adjacent °C field. If Delta Temp, the item's temperature is equal to the value in the adjacent °C field plus the parent's temperature.	1, 3–4	Fixed Temp Delta Temp
°C	Temperature in °C	1, 3–4	Value in °C
Cur. Temp.	Actual current temperature	1, 3, 4	Set by RAM Commander
FRp	Predicted (calculated) failure rate	1, 3–4	Set by RAM Commander
FRu	User defined failure rate. Takes effect only if FR source is `user defined` (see above)	3–4	User defined floating point value
Source of FRu	Source of user defined failure rate	3–4	User defined string value
FRf	Failure rate from field data or from FRACAS. Takes effect only if FR source is FRACAS (see page 594)	3–4	Value of Lf
FRa	Allocated failure rate. Takes effect only if FR source is `Allocated` (see page 594)	1, 3–4	Value of allocated lambda
Complexity for FRa	Complexity factor for reliability allocation. This parameter is valid if you selected Allocated failure rate	3–4	Value of complexity factor
Field factor	Field factor multiplier for computing item failure rate	3–4	

Field name	Description	Dialog boxes with this field	Values or field type
Duty cycle	Duty cycle multiplier for computing item failure rate	3	
Mult. factor	Multiplicative factor multiplier for computing item failure rate	3–4	
Add. factor	Additive factor multiplier for computing item failure rate	3–4	
Item Failure	Computed failure rate value of current item	3–4	Set by RAM Commander
Status Check	Check status	3–5	Set by RAM Commander --- = no status Err = Error Warn = Warning O.K. = OK
Status Calc	Calculation status	3–5	Set by RAM Commander --- = no status Err = Error Warn = Warning O.K. = OK
Catalog number	Item catalog number	1–2	User defined string
Military number	Item military number	2	User defined string
Generic name	Item generic name used in library searches for component	2	User defined string
Description	Item description	1–2	User defined string
Remark	Item remark	2	User defined string
Nc	Number of on/off cycles per 1000 hrs	1, 4	

Field name	Description	Dialog boxes with this field	Values or field type
Cur. Nc	Current number of on/off cycles per 1000 hrs (set to parent's Nc if `---` in Nc field)	1, 4	Set by RAM Commander
Method of Mct calculation	If `user defined`, you must fill in the Method field	5	Default User defined
(No prompt)	Maintenance corrective time source flag	5	Calculated User defined Allocated
Mct(c)	Calculated maintenance corrective time calculated	5	Set by RAM Commander
Mct(m)	User defined maintenance corrective time	5	User defined floating point value
Mct(a)	Allocated maintenance corrective time	5	User defined floating point value
Complexity for Mct(a)	Complexity for allocated Mct	5	
MLH(c)	Calculated mean labour hour	5	Set by RAM Commander
MLH(m)	User defined mean labour hour	5	User defined floating point value
False Alarm Rate	False alarm rate	5	
Level of replace	Level of replace	5	Inapplicable Organizational Intermediate Depot

Field name	Description	Dialog boxes with this field	Values or field type
Level of repair	Level of repair	1, 5	Inapplicable Organizational Intermediate Depot Discard
Ambiguity factor		1, 5	Set by RAM Commander
MTTRa	Allocated MTTR	1, 5	User defined floating point value
Conf. Level	Confidence level	1, 5	70%, 75%,80%, 85%, 90%, 95%, 98%, 99%, 99.5%, 99.9%
Mct [Hrs]	Calculation result	5	Set by RAM Commander
MLH	Mean labour hours	1, 5	Set by RAM Commander
MTTR	Mean time to repair	1, 5	Set by RAM Commander
Mct max	Calculation result for a given confidence level	1, 5	Set by RAM Commander
N1…N5	Fault isolation to N1…N5 parts with probability %1…%5	1, 5	User defined non-negative integer
%1…%5	Probability of fault isolation to N1…N5 parts	1, 5	User defined integer between 0–100
Item price	Item's price in selected currency	6	User defined value
Currency	Currency code	6	$US FF

Field name	Description	Dialog boxes with this field	Values or field type
Item weight	Item weight in kilograms	6	User defined floating point value
Item volume	Item volume	6	User defined floating point value
Power consumption	Power consumption in watts	6	User defined floating point value
Current consumption	Current consumption in Amperes	6	User defined floating point value
Burn-in Temperature ^{o}C	Burn-in temperature in ^{o}C	1, 6	User defined floating point value
Burn-in Time	Burn-in time in hours	1, 6	User defined positive integer
PI FY	Result from burn-in calculation. First year multiplier (ratio of the first year failure rate to the steady state failure rate).	6	Set by RAM Commander.

List of Item Codes

(---) Assembly
Breaker
Bubble Memory
Capacitor
Connection
Connector
Crystal
Filter
Fuse
HF Diode
HF Transistor
Hybrid
IC Analog
IC Digital
IC Memory
Inductive
Lamp
Laser Diode
Laser Gas
Laser Solid
LF Diode
LF Transistor
Meter
Miscellaneous
Optoelectronic
Potentiometer
PWB
Relay
Resistor
Rotating
SAW
Substrate
Switch
Tube

Appendix C

Methods and Environments

RAM Commander's data base contains data from the following operating reliability prediction methods. This list is complete as of January 1, 1996. ALD will continue to update its data base support as new methods are issued.

Operating Methods

ALCATEL
BELLCORE Issue 5
BELLCORE Issue 6
BRITISH TELECOM HRD4
BRITISH TELECOM HRD5
CNET RDF93 rev 02/95
GJB299 Part Count
GJB299 Part Stress
HRD5 TELECOMM
ITALTEL IRPH93
MIL-217E-1 P. stress
MIL-217F-1 P. count
MIL-217F-1 P. stress
MIL-217F-2 P. count
MIL-217F-2 P. stress
NPRD-95
NSWC-92L01 Mechanics
Siemens SN29500-1
Table/Packed to Box
Telcordia Issue 1
UTE C 80-810

Non-operating Methods

MIL-217E-1 draft

NPRD-95

RADC-TR-85-91

Table/Packed to Box

Reliability Toolkit (1995)

Maintainability Methods

MIL-STD-472, Procedure 5 Method A

Defined Environments for Selected Operating Methods

Environ-ment	MIL 217E1	MIL 217FN1, FN2, Alcatel	Bellcore Issue 5	Bellcore 6 Telcordia 1	Italtel IRPH93	British Telecom HRD4	HRD5 Telecomm	CNET RDF 93	GJB299	RADC-TR-85-91 MIL-217E-1 draft
AIA	Airborne, Inhabited, Attack	Airborne, Inhabited, Fighter								Airborne, Inhabited, Attack
AIB	Airborne, Inhabited, Bomber	Airborne, Inhabited, Cargo								Airborne, Inhabited, Bomber
AIC	Airborne, Inhabited, Cargo	Airborne, Inhabited, Cargo		Airborne, commercial (AC)			Portable & non-stationary used, Temperature controlled	Airborne, Benign	Airborne, Inhabited, Cargo	Airborne, Inhabited, Cargo
AIF	Airborne, Inhabited, Fighter	Airborne, Inhabited, Fighter						Airborne, Moderate	Airborne, Inhabited, Fighter	Airborne, Inhabited, Fighter
AIT	Airborne, Inhabited, Trainer	Airborne, Inhabited, Cargo								Airborne, Inhabited, Trainer
ARW	Airborne, Rotary Winged	Airborne, Rotary Winged							Ground, Mobile, Violence (GM2)	Airborne, Rotary Winged

Environ-ment	MIL 217E1	MIL 217FN1, FN2, Alcatel	Bellcore Issue 5	Bellcore 6 Telcordia 1	Italtel IRPH93	British Telecom HRD4	HRD5 Telecomm	CNET RDF 93	GJB299	RADC-TR-85-91 MIL-217E-1 draft
AUA	Airborne, Uninhabited, Attack	Airborne, Uninhabited, Fighter								Airborne, Uninhabited, Attack
AUB	Airborne, Uninhabited, Bomber	Airborne, Uninhabited, Cargo								Airborne, Uninhabited, Bomber
AUC	Airborne, Uninhabited, Cargo	Airborne, Uninhabited, Cargo						Airborne, Severe	Airborne, Uninhabited, Cargo	Airborne, Uninhabited, Cargo
AUF	Airborne, Uninhabited, Fighter	Airborne, Uninhabited, Fighter						Airborne, Extremely Severe	Airborne, Uninhabited, Fighter	Airborne, Uninhabited, Fighter
AUT	Airborne, Uninhabited, Trainer	Airborne, Uninhabited, Cargo								Airborne, Uninhabited, Trainer
CL	Cannon, Launch	Cannon, Launch								Cannon, Launch
GB	Ground, Benign	Ground, Benign	Ground, Fixed, Controlled	Ground, Fixed, Controlled	Weather protected	Ground, Benign	Weather protected, Temperature controlled	Ground, Stationary, Weather-protected	Ground, Benign	Ground, Benign
GF	Ground, Fixed	Ground, Fixed	Ground, Fixed, Uncontrolled	Ground, Fixed, Uncontrolled	Non weather protected	Ground, Fixed	Non - weather protected	Ground, Stationary, Non Weather-protected	Ground, Fixed, Generic (GF1)	Ground, Fixed

Environ-ment	MIL 217E1	MIL 217FN1, FN2, Alcatel	Bellcore Issue 5	Bellcore 6 Telcordia 1	Italtel IRPH93	British Telecom HRD4	HRD5 Telecomm	CNET RDF 93	GJB299	RADC-TR-85-91 MIL-217E-1 draft
GM	Ground, Mobile	Ground, Mobile	Ground, Mobile (both vehicular mounted and portable)	Ground, Mobile (both vehicular mounted and portable)	Mobile	Ground, Mobile	Ground vehicle installations, Protected	Ground, Non Stationary, Benign	Ground, Mobile, Smooth (GM1)	Ground, Moign
GMS	Ground, Missile Silo	Ground, Benign					Weather protected, Non temperature controlled		Ground, Missile Silo	
MFA	Airbreathing Missile, Flight	Missile, Flight								Airbreathing Missile, Flight
MFF	Missile, Free Flight	Missile, Flight								Missile, Free Flight
ML	Missile, Launch	Missile, Launch						Satellite, Launch	Missile, Launch	Missile, Launch
MP	Manpack	Ground, Mobile					Partly weather protected and non - weather protected	Ground, Non Stationary, Severe	Manually transport	Manpack
NH	Naval, Hydrofoil	Naval, Unsheltered							Naval, Sheltered, Generic (NS2)	Naval, Hydrofoil

Environ-ment	MIL 217E1	MIL 217FN1, FN2, Alcatel	Bellcore Issue 5	Bellcore 6 Telcordia 1	Italtel IRPH93	British Telecom HRD4	HRD5 Telecomm	CNET RDF 93	GJB299	RADC-TR-85-91 MIL-217E-1 draft
NS	Naval, Sheltered	Naval, Sheltered						Naval, Benign	Naval, Sheltered, Benign (NS1)	Naval, Sheltered
NSB	Naval, Submarine	Naval, Sheltered							Submarines	Naval, Submarine
NU	Naval, Unsheltered	Naval, Unsheltered					Ship environments, Non - weather protected	Naval, Severe	Naval, Unsheltered	Naval, Unsheltered
NUU	Naval, Undersea Unsheltered	Naval, Unsheltered							Ground, Fixed, Atrocious weather (GF2)	Naval, Undersea Unsheltered
SF	Space, Flight	Space, Flight		Spacebased, commercial (SC)				Satellite, Flight	Space, Flight	Space, Flight
USL	Undersea, Launch	Missile, Launch								Undersea, Launch

Notes on Environments and Operating Methods

BRITISH TELECOM HRD4

GB Ground, Benign: Nearly zero environmental stress with optimum conditions for operation and maintenance. Typical applications are in main exchange buildings, environmentally controlled remote exchanges or cabinets (including Case Repeater Equipment) and environmentally controlled subscribers' premises. The equipment is operated in a protected environment, free from significant shock and vibration with the temperature of the air immediately surrounding the component not exceeding 55°C and relative humidity rarely exceeding 70% at 15°C.

GF Ground, Fixed: Conditions less than ideal, with some environmental stress and limited maintenance. Typical applications are manholes, remote terminals and areas in subscribed premises subject to shock and vibration or temperature and atmospheric variations.

GM Ground, Mobile: Conditions more severe than for Ground, fixed, mostly for shock and vibration. There is less maintenance attention and equipment is susceptible to operator abuse. Typical applications are mobile telephones, portable operating equipment and test equipment.

Bellcore Issue 5

GB Ground, Fixed: Nearly zero environmental stress with optimum engineering operation and maintenance. Typical applications are central office, environmentally controlled vaults, environmentally controlled remote shelters, and environmentally controlled customer premise areas.

GF Ground, Fixed: Some environmental stress with limited maintenance. Typical applications are manholes, poles, remote terminals, customer premise areas subject to shock, vibration, temperature, or atmospheric variations.

GM Ground, Mobile: Conditions more severe than GF, mostly for shock and vibration. More maintenance limited and susceptible to operator abuse. Typical applications are mobile telephones, portable operating equipment, and test equipment.

Bellcore Issue 6, Telcordia Issue 1

GB Ground, Fixed: Nearly zero environmental stress with optimum engineering operation and maintenance. Typical applications are central office, environmentally controlled vaults, environmentally controlled remote shelters, and environmentally controlled customer premise areas.

GF Ground, Fixed: Some environmental stress with limited maintenance. Typical applications are manholes, poles, remote terminals, customer premise areas subject to shock, vibration, temperature, or atmospheric variations.

GM Ground, Mobile: Conditions more severe than GF, mostly for shock and vibration. More maintenance limited and susceptible to operator abuse. Typical applications are portable and mobile telephones, portable operating equipment and test equipment.

AIC Airborne, commercial: Conditions more severe than GF, mostly for pressure, temperature, shock and vibration. In addition, the application is more maintenance limited than for GF. Typical applications are in the passenger compartment of commercial aircraft.

SF Spacebased, commercial: Low earth orbit. Conditions as for AIC, but with no maintenance. Typical applications are commercial communication satellites.

GJB299

GB Normally weather, almost no mechanical stress, and readily accessible to maintenance, such as laboratory with temperature and humidity controlled or large ground station.

GMS Typical conditions in ground silo in which. missiles and its assistant equipment are set.

GF (GF1) Typical conditions in the inside of generic building or on permanent racks with good ventilation. With moderate strike and vibration. Such as environment in which permanent installation radar, communications facilities, TV and recorder etc. are installed.

NUU (GF2) Ground conditions with poor protected facilities for weather and Underground conditions. Severe conditions related to high temperature, low temperature, difference in temperature, severe humidity, mildew, salt vapor and chemic gas, etc.

GM (GM1) Equipment installed on vehicles which moved smoothly. With strike and vibration conditions, such as special vehicle running on highroad, carriage of train.

ARW (GM2) Equipment installed on tracked vehicles. With violent strike and vibration conditions related to violently moving. and with restricted control of ventilation, temperature and humidity.

MP Equipment manually transported in field environment. With poor maintenance conditions.

NSB Typical conditions in submarines.

NS (GS1) Include sheltered or below deck conditions on surface ship which travel smoothly. Unserious exposed to salt vapor and water vapor. Such as air-conditioning cabin of large cargo ship traveling near coastal waters and ship traveling in freshwater.

NH (GS2) Sheltered conditions without exposed to weather conditions, but often with violent strike and vibration. Include sheltered or below deck conditions on surface ship.

NU Typical conditions in board of ship. Unprotected surface ship borne, often with violent strike and vibration, exposed to weather conditions and immersed in salt water.

AIF Typical conditions in fighter which can be occupied by pilots. Without high temperature, high pressure, and violent strike and vibration.

AUF Severe conditions of high temperature, high pressure, and violent strike and vibration, etc., such as equipment compartment and bomb bay in fuselage, tail, wing of fighter.

AIC Typical conditions in cargo compartments which can be occupied by an aircrew.

AUC Environmentally uncontrolled areas which cannot be inhabited by an aircrew during flight.

SF Earth orbital. Approaches benign ground conditions. Vehicle neither under powered flight nor in atmospheric reentry, such as installing environment of electronic equipment in satellites.

ML Severe conditions related to missile launch, solid rocket motor propulsion powered flight, space vehicle boost into orbit, and vehicle re-entry and landing by parachute, such as noise, vibration, strike, and other severe conditions.

Appendix D

Component Import Formats

The following tables list, by screen name, the various input fields used in import files.

Tree General

Field name	Length	Type	Description
TRrefdes	10	Text	Reference designator
TRdepth	2	Int	Tree depth level in the Import file: The first line (i.e. top of the importing Sub tree) must always have a depth equal to 1. Note that the RAM Commander handles up to 10 tree levels (including project top).
TRicode	4	S text	Predefined shortcuts of Item codes: Family type is determined by the RAM Commander due to the Item code. Mechanical and Electro Mechanical item codes are moved to other families. Tree hierarchy items (assemblies) must have the 'UNDEF' item code. If not specified or not included set to UNDEF.
TRqty	4	Int	Quantity of item(s)
TRgname	21	Text	Generic name (Short library code)
TRcatnum	31	Text	Catalog Number (Factory ID): Library may be accessed through the Cross Reference option.
TRmilnum	31	Text	Military Number. Library may be accessed through the Cross Reference option.
TRpN	31	Text	Part name (Manufacture ID). Library may be accessed through the Cross Reference option.
FindName	31	Text	one of the four item's identifiers (Generic name or Catalog Number or Military Number or Part name). If one column (field) of an Import file includes two or more item's identifiers (e.g. Generic names and Military Numbers) then you should use this field type. Upon completing the RTF import procedure you must run the 'Load from library' option to retrieve imported data.
TRdscr	41	Text	Item description.
TRrem	21	Text	Item remark.
TRManuf	10	Text	Manufacturer's name
TRlcn	19	Text	Logistics Control Number

Field name	Length	Type	Description
TRSPTTm	12	Float	Spare Part Turnaround time
TRSPCRat	12	Float	Spare Part Condemnation Rate
TRSPMinQ	4	Int	Spare Part Minimal Qty
TRSPMaxQ	4	Int	Spare Part Maximal Qty
TRSPSMR	9	Text	SMR
Ignore	n	Text	Field that should be ignored. n=Number of chars to be ignored (equal to 1 by default). This field is used to ignore columns of text file and/or make blanks between fields. Max width 150 chars.

Operating Data

Field name	Length	Type	Description	Notes
OPftemp	9	Float	Fix temperature.	If both 'Fix temperature' and 'Delta temperature' fields are defined then Fix temperature will be used.
OPdtemp	9	Float	Delta temperature.	If both 'Fix temperature' and 'Delta temperature' fields are defined then Fix temperature will be used.
OPenv	3	S text	Environment.	All acceptable ENV values are listed in Section 2 of this Appendix.
OPmldscr	31	Text	Manual LAMBADA (L) source description.	
OPlswitch	2	S text	Switch of Lup definition method	The following values are acceptable: CA=L Calculated; MA=L manually defined by user; FR=L from FRACAS; AL L allocated.
OPlcal	9	Float	L calculated.	
OPlman	9	Float	L manually defined by user.	
OPlfra	9	Float	L from FRACAS.	
OPlall	9	Float	L allocated.	
OPdc	9	Float	Duty cycle.	
OPkfld	9	Float	Field factor.	
OPlcmpl	9	Float	L allocation weight (complexity).	

Non-operating Data

Field name	Length	Type	Description	Notes
NOftemp	9	Float	Fix temperature.	If both 'Fix temperature' and 'Delta temperature' fields are defined then Fix temperature will be used.
NOdtemp	9	Float	Delta temperature.	If both 'Fix temperature' and 'Delta temperature' fields are defined then Fix temperature will be used.
NOenv	3	S text	Environment.	All acceptable ENV values are listed in Section 2 of this Appendix.
NOmldscr	31	Text	Manual L source description.	
NOlswitch	2	S text	Switch of Lup definition method.	The following values are acceptable: CA=L Calculated; MA=L manually defined by user; FR=L from FRACAS; AL=L allocated.
NOlcal	9	Float	L calculated.	
NOlman	9	Float	L manually defined by user.	
NOlfra	9	Float	L from FRACAS.	
NOlall	9	Float	L allocated.	
NOnc	9	Float	Number of cycles / 1000 Hours.	
NOkfld	9	Float	Field factor.	
NOlcmpl	9	Float	L allocation weight (complexity).	

Maintainability Data

Field name	Length	Type	Description	Notes
MNlorpr	2	S text	Level of repair.	The following values are acceptable: UN=Unapplicable; OR=Organizational; IN =Intermediate; DE=Depot; DI=Discard (i.e. not reparable).
MNlorpl	2	S text	Level of replace.	The following values are acceptable: UN=Unapplicable; OR=Organizational; IN=Intermediate; DE=Depot.
MNmswitch	2	S text	MCT & MMH source switch: CA MCT & MMH Calculated; MA MCT & MMH Manual; L MCT Allocated.	
MNmctcal	9	Float	MCT Calculated.	
MNmctman	9	Float	MCT manually defined by user.	
MNmctall	9	Float	MCT Allocated.	
MNmmhcal	9	Float	MMH Calculated.	
MNmmhman	9	Float	MMH manually defined by user.	
MNmstcmpl	9	Float	Maintainability allocation weight.	

Miscellaneous Data

Field name	Length	Type	Description
MIcurency	3	S text	Currency: USD US dollars; FF French Francs.
MIprice	9	Float	Item price.
MIcur	9	Float	Current consumption [A].
MIpwr	9	Float	Power consumption [W].
MIweight	9	Float	Weight [Kg].
MIvolume	9	Float	Volume [M3].

Stress Information

Stress	150 chars	Text	Stress information.

Example of Stress data:

```
TJC=5;VSR=0.4;
```

Appendix E

Import File Abbreviations

The following abbreviations can be used for import file field values instead of their full nomenclature that appears on screen list boxes.

Item Code Abbreviations

Abbreviation	Definition
BUBM	Bubble memory
CAPC	Capacitor
CBRK	Circuit breaker
CIND	Coil, inductive device
CONR	Connector and IC sockets
CONT	Connection
FLTR	Filter (can be tree hierarchy item)
FUSE	Fuse
HFDI	High frequency diode
HFTR	High frequency transistor
HYBR	Hybrid IC (tree hierarchy item
ICAN	IC Analog
ICDI	IC Digital
ICME	IC Memory
LAMP	Lamps incandescent

Abbreviation	Definition
LFDI	Low frequency diode
LFTR	Low frequency transistor
LGAS	Laser gas
LSEM	Laser Semiconductor device
LSOL	Laser solid state
METR	Meter
MISC	Miscellaneous
OPTE	Optoelectronic device
POTN	Potentiometer
PWBD	Printed wiring board
QCRY	Quartz Crystal
RELY	Relay (can be tree hierarchy item)
RESI	Resistor
ROTD	Rotating device
SACW	Surface acoustic wave
SUBS	Substrate (tree hierarchy item)
SWIT	Switch
TUBE	Tube
UNDF	Undefined tree hierarchy item

Hierarchy Item Codes

UNDF	is used for hierarchy item or item that represents a purchased part with User (manually) defined failure rate.
FLTR, RELY	if they have no children, they are calculated as usual; if one of them has "children", it is considered to be an assembly and gets "children's" failure rates.
Hybrid are defined as follows: HYBR, then SUBS on next lower level, and then components on the next lower level	

Environment Codes

Abbreviation	Definition
AIA	Airborne, Inhabited, Attack
AIB	Airborne, Inhabited, Bomber
AIC	Airborne, Inhabited, Cargo
AIF	Airborne, Inhabited, Fighter
AIT	Airborne, Inhabited, Trainer
ARW	Airborne, Rotary, Winged
AUA	Airborne, UnInhabited, Attack
AUB	Airborne, UnInhabited, Bomber
AUC	Airborne, UnInhabited, Cargo
AUF	Airborne, UnInhabited, Fighter
AUT	Airborne, UnInhabited, Trainer
CL	Cannon, Launch
GB	Ground, Benign
GF	Ground, Fix
GM	Ground, Mobile
GMS	Ground, Missile Silos
MFA	Airbreathing, Missile, Flight
MFF	Missile, Free Flight
ML	Missile, Launch
MP	Manpack
NH	Naval, Hydrofoil

Abbreviation	Definition
NS	Naval, Sheltered
NSB	Naval, Submarine
NU	Naval, UnSheltered
NUU	Naval, Undersea, UnSheltered
SF	Space, Flight
USL	Undersea, Launch

Stress Codes

Part I (IC memory - Hf transistor)

Stress parameters	IC memory	IC analog	IC digital	Resistor	Potentiometer	Capacitor	Switch	Relay	Lf diode	Lf transistor	Hf diode	Hf transistor	Stress parameters
TJC	+	+	+						+	+	+	+	TJC
PDI	+	+	+	+	+		+		+	+	+	+	PDI
PSR	+	+	+	+	+		+		+	+	+	+	PSR
VSR		+		+	+	+	+	+	+	+		+	VSR
VAP	+	+	+	+	+	+	+	+	+	+		+	VAP
VAA						+							VAA
VGS	+	+	+							+		+	VGS
VGA	+	+	+							+		+	VGA
VDS										+		+	VDS
VDA										+		+	VDA
CSR		+					+	+	+	+	+	+	CSR
CAP		+					+	+	+	+	+	+	CAP
FRA	+		+										FRA
FRS	+		+										FRS
Stress parameters	IC memory	IC analog	IC digital	Resistor	Potentiometer	Capacitor	Switch	Relay	Lf diode	Lf transistor	Hf diode	Hf transistor	Stress parameters

Part II (Optoelectronic - Breaker)

Stress parameters	Opto-electronic	Bubble memory	Conn-ector	Indu ctive	Fuse	Laser Diode	SAW	Lamp	Filter	Breaker	Stress parameters
TJC	+	+				+					TJC
PDI	+	+				+	+				PDI
PSR	+	+				+	+				PSR
VSR	+		-	+	+			+	+		VSR
VAP	+			+	+			+	+		VAP
VAA											VAA
VGS			+								VGS
VGA			+								VGA
VDS											VDS
VDA											VDA
CSR	+		+	+	+			+	+	+	CSR
CAP	+		+	+	+			+	+	+	CAP
FRA											FRA
FRS											FRS
Stress parameters	Opto-electronic	Bubble memory	Conn-ector	Indu ctive	Fuse	Laser Diode	SAW	Lamp	Filter	Breaker	Stress parameters

Stress Parameter Abbreviations

Abbreviation	Description
CAP	Applied current
CSR	Current stress ratio (CSR)
PDI	Power dissipation
PSR	Power stress ratio (PSR)
TJC	Delta temperature junction to case (ambient)
VAA	Applied voltage (alternative)
VAP	Applied voltage (direct)
VDA	Applied voltage drain source
VDS	Voltage stress ratio drain source (VSRds)
VGA	Applied voltage gate source
VGS	Voltage stress ratio gate source (VSRgs)
VSR	Voltage stress ratio (VSR)
VRA	Rated Voltage
VGR	Rated Voltage gate source
VDR	Rated Voltage drain source
CRA	Rated Current
PRA	Rated Power
FRA	Frequency Applied
FRS	Frequency SR

Appendix F

Library Import File Abbreviations and Field Names

- CAPC Capacitor
- CIND Coil, inductive device
- CONR Connector and IC sockets
- FUSE Fuse
- HFDI High frequency diode
- HFTR High frequency transistor
- ICAN IC Analog
- ICDI IC Digital
- ICME IC Memory
- LFDI Low frequency diode
- LFTR Low frequency transistor
- OPTE Optoelectronic device
- POTN Potentiometer
- PWBD Printed wiring board
- QCRY Quartz Crystal
- RELY Relay (can be tree hierarchy item)
- RESI Resistor
- SWIT Switch
- BUBM Bubble memory

- CBRK Circuit breaker
- CONT Connection
- FLTR Filter
- HYBR Hybrid IC
- LAMP Lamps incandescent
- LGAS Laser gas
- LSEM Laser Semiconductor device
- LSOL Laser solid state
- METR Meter
- MISC Miscellaneous
- ROTD Rotating device
- SACW Surface acoustic wave
- SUBS Substrate
- TUBE Tube

Library Import File Field Names

Field name	Type	ICME	ICAN	ICDI	RESI	POTN	CAPC	SWIT	RELY	CONR	LFDI	LFTR	HFDI	HFTR	OPTE	CIND	PWBD	QCRY	FUSE	Description
TYPE	S	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+		Device type (style)
TECH	S	+	+	+													+			Technology
PACK	S	+	+	+					+		+	+	+	+	+	+				Package
QUAL	S	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	Quality level
PINS	N	+	+	+																# Pins
BITS	N	+		+																# Bits
GATE	N			+																# Gates
TRNS	N		+																	# Transistors
TETA	N	+	+	+							+	+	+	+	+					Theta jc [°C /W]
TMAX	N	+	+	+							+	+	+	+	+					T junction max °C
PMAX	N	+	+	+	+	+					+	+	+	+	+	+				Power-rated dissip. [W]
VMAX	N	+	+	+		+	+				+	+		+	+					Voltage rated [V]
IMAX	N							+	+		+									Current rated [A]
APPL	S		+								+	+	+	+						Application
RESS	S				+	+														Suffix for resistance
RESI	N				+	+	+													Resistance
CAPS	S						+													Suffix for capacitance
CAPI	N						+													Capacitance
HFTH	S													+						HFTR Matching
HFTM	S													+						HFTR Metalization
OPTL	S														+					OPTE Logic exists
OPTC	N														+					# characters
OPTH	N														+					# channels

Field name	Type	ICME	ICAN	ICDI	RESI	POTN	CAPC	SWIT	RELY	CONR	LFDI	LFTR	HFDI	HFTR	OPTE	CIND	PWBD	QCRY	FUSE	Description
CAPT	S						+		+	+						+	+			Max rated temperature
ESBT	S	+																		EEPROM Subtype
EECC	S	+																		EEPROM Error Cor. Code
PRYR	N	+	+	+																Years of production
MTYR	N	+	+	+																Maturity year
MNYR	N	+	+	+																Manufacturing year
UTIL	N	+	+	+																Utilization period
VLMP	S			+																VHSIC Manuf. process
VLDA	N			+																VHSIC Die Area [cm²]
VLFS	N			+																VHSIC Feature Size [micr]
VLVR	N			+																VHSIC Voltage Range [V]
NETR	N				+															# Resistors
RESC	S				+															RE & RER Characteristic
POTR	S					+														RR Construction
POTR	S					+														RP Construction
POTT	N					+														# Tap
CAPC	S						+													CAPC Construction
CAPF	S						+													CAPC Configuration
LFDC	S										+									LFDI Construction
RES1	N				+	+														Stress–Temper. 1
RES2	N				+	+														Stress–Temper. 2
RET1	N				+	+														Temper. 1 °C

Field name	Type	ICME	ICAN	ICDI	RESI	POTN	CAPC	SWIT	RELY	CONR	LFDI	LFTR	HFDI	HFTR	OPTE	CIND	PWBD	QCRY	FUSE	Description
RET2	N				+	+	+													Temper. 2 °C
SRSB	S	+																		SRAM Subtype
GSBT	S			+																GAAS Subtype
FRAG	S										+									Fragility
ISTR	S										+									Internal structure
FCO	S							+	+											Contact form
EVAL	S							+	+	+						+	+	+	+	Evaluation for CNET
NCON	N							+		+										# active contacts
KEYS	N							+												# keys (touches)
CINT	S								+											# cont interrupteurs
CINV	S								+											# cont inverseurs
PROT	S								+											Protection type
COUR	S								+											Courant for CNET
MATR	S									+										Material
CSZE	S									+										Contact size
SURF	N															+	+			Surface
WIDW	S																+			Largeur domin de pistos
LAYR	N																+			# layers
HOWV	N																+			# holes by wave
HOHN	N																+			# holes by hand
WIRE	N																+			# wires
RFEQ	N																	+		Frequency

Appendix G

Reliability Growth Modeling

RAM Commander's reliability growth module is the Duane method as described in MIL-STD-1635. In this model, the tested mean time between failure (MTBF) is proportional to T^{α} where T is the cumulative operating test time and α is the growth rate index. On a log-log plot, the growth regression line is linear with slope α.

The *cumulative mean time before failure* ($MTBF_c$) is normally measured during testing and then divided by (1 - α) to convert it to the current instantaneous mean time before failure $MTBF_i$. $MTBF_i$ is then plotted parallel to the $MTBF_c$ at an offset of $1/(1 - \alpha)$. The test time at which this line reaches the required MTBF is the expected duration of the reliability growth test.

RAM Commander uses Bootstrap, a new statistical technology that enables the user to calculate accurate confidence intervals for the main parameters of the Duane model by obtaining a large number of samples. Details of this method have been published in the paper "Bootstrap Technology for RAM Analysis", Z. Bluvband and L. Peshes, *Proceedings of the Symposium on New Directions in Military Reliability, Availability and Maintainability (RAM) Analysis*, Maryland, USA, 1993.

Derivation of Model Equations

According to the Duane formulation:

$$\lambda_{\Sigma} = \frac{F}{E} KH^{-\alpha}$$

where:

λ_{Σ}	cumulative failure rate
H	total test hours
F	failure during H hours
K	condition-dependent coefficient
α	growth rate

The original mathematical model was expressed in terms of cumulative failure rate. However, since equipment reliability is generally expressed in terms of MTBF, the following expression is more frequently used:

$$MTBF_R = MTBF_I \left(\frac{T_I}{t_i} \right)$$

where:

$MTBF_R$	required MTBF
$MTBF_I$	initial MTBF
t_i	time at which initial data point is plotted (preconditioning time)
T_i	time at which the instantaneous MTBF of the equipment under test will reach the required MTBF

Differentiating the equation with respect to time, we receive

$$\lambda(t) = \frac{\partial F}{\partial H} = (1 - \alpha) KH^{-\alpha} = (1 - \alpha)\lambda_{\Sigma}$$

Thus, the current instantaneous failure rate is $(1 - \alpha)$ times the cumulative failure. That is, the instantaneous MTBF is $1/(1 - \alpha)$ times the cumulative MTBF.

The instantaneous MTBF may be interpreted as the MTBF that the equipment under test would exhibit if we stopped the reliability growth and continued testing. Thus, on a logarithmic plot, instantaneous or current-status curves are straight lines displaced a fixed distance from the cumulative plot by a factor of $(1 - \alpha)$.

The cumulative MTBF ($MTBF_c$) is normally measured during testing and then converted to the instantaneous (or current) MTBF ($MTBF_i$) by dividing by $(1 - \alpha)$, that is:

$$MTBF_i = \frac{MTBF_c}{1 - \alpha}.$$

Appendix H

Maintainability Prediction Modeling

This appendix presents theoretical development for five maintainability modeling techniques:

- Maintenance Corrective Time (Mct)
- Mean time to repair (MTTR)
- Ambiguity factor
- Maximum Corrective Maintenance Time
- Mean Maintenance Man-hours per Maintenance Action (MMH/MA)

Maintenance Corrective Time

The formula for computing Mct is

$$Mctj = TPREPj + TISOj + TDISj + TR/Rj + TREASj + TCALj + TVERj + TSTj$$

where:

Mct_j	average maintenance corrective or repair time for the *j*th replaceable item
T_{PREPj}	average preparation time for the *j*th replaceable item
T_{ISOj}	average fault isolation time for the *j*th replaceable item
T_{DISj}	average disassembly time for the *j*th replaceable item
$T_{R/Rj}$	average time to remove/replace (interchange) the *j*th replaceable item

T_{REASj}	average reassembly time for the *j*th replaceable item
T_{CALj}	average calibration time for the *j*th replaceable item
T_{VERj}	average verification time for the *j*th replaceable item
T_{STj}	average time of start-up for the *j*th replaceable item

Mean Time to Repair

The formula for computing MTTR is

$$MTTR = \frac{\sum_{j=1}^{N} \lambda_j \left[T_{PREPj} + T_{ISOj} + S(T_{DISj} + T_{R/Rj} + T_{REASj} + T_{CALj} + T_{VERj}) + T_{STj}\right]}{\sum_{j=1}^{N} \lambda_j}$$

where:

N	number of replaceable items on the next lower level of the product tree
λ_j	failure rate of the *j*th replaceable item
S	Ambiguity factor, as computed below

Ambiguity Factor

The ambiguity factor is the average number of iterations required to correct a fault, and is computed as

$$S = \frac{1}{100} \sum_{i=1}^{K} (X_i - X_{i-1}) \frac{(N_i + N_{i-1} + 1)}{2}$$

where:

X_i	probability of fault isolation to N_i replaceable items.
	$X_1\% < X_2\% < X_3\% < X_4\% < 100\%$.
$0 < N_i$	Number of items in the i^{th} ambiguity group
$X_0 = N_0 = 0$	

It is assumed that failure is isolated to an entire group of $0 < N_i < 99$ (for i=1…5) parts. The probability that the fault will be isolated for N_5 parts is $X_5 = 100\%$.

You can use up to 5 groups (i.e., $i \leq 5$). The probability of the highest one must be equal to 100%. Furthermore, the inequality

$$X_1\% < X_2\% < X_3\% < X_4\% < X_5\%$$

must hold.

Maximum Corrective Maintenance Time

The Maximum Corrective Maintenance Time for the ϕ-th percentile $Mct_{max}(\phi)$ is the value of corrective maintenance time below which ϕ percent of all maintenance actions are expected to be completed.

$$Mct_{max}(\phi) = \exp[\log MTTR + \phi\sigma_{Mct}]$$

where:

$$\sigma_{Mct} = \sqrt{\frac{\sum_{i=1}^{N}(\log Mct_i)^2 - [(\sum_{i=1}^{N} \log Mct_i)^2 / N]}{N-1}}$$

Mean Maintenance Man-hours per Maintenance Action

Component level

$$MMH / MA = \sum_{i=1}^{K} MMH_i = \sum_{i=1}^{K} MP_i T_i$$

where:

MMH_i	Mean maintenance man-hours required for the *i*th maintenance task (preparation, fault isolation, disassembly, reassembly, etc.)
T_i	average time to perform the *i*th maintenance task (see Mct definition above)
MP_i	Manpower required for the *i*th maintenance task
K	number of maintenance tasks required (preparation, fault isolation, disassembly, reassembly, etc.)

Assembly Level

$$\frac{MMH_{AS}}{MA} = \frac{\sum_{j=1}^{N} \lambda_j [MMH_{PREP} + MMH_{ISO} + S(MMH_{D/R} + MMH_{R/Rj} + MMH_{CALj} + MMH_{VERj}) + MMH_{STj}\ ]}{\sum_{j=1}^{N} \lambda_j}$$

where:

MMH_{PREPj}	average preparation MMH
MMH_{ISOj}	average fault isolation MMH.
$MMH_{D/Rj}$	average disassembly / reassembly MMH
$MMH_{R/Rj}$	average MMH of remove / replace (Interchange)
MMH_{CALj}	average calibration MMH.
MMH_{VERj}	average verification MMH
MMH_{STj}	average start-up MMH
N	number of replaceable items on the next lower level of the product tree.
λ_j	failure rate of the *j*th replaceable item
S	ambiguity factor

The value of the *ambiguity factor* S is used in calculating the MTTR for an assembly.

Maintainability Allocation

Maintainability allocation for each *i*th child of the current item is computed according to the formula:

$$Mct(son_i) = MTTR_a(item) + W_M(son)\left(\frac{L(son_i) * Qty(son_i)}{\sum W_M(son_i) * L(son_i) * Qty(son_i)}\right)$$

where:

$Mct(son_i)$	allocated Mct of *i*th child
W_M	weighing factor for maintainability allocation
Qty	quantity of identical lower level items
$L(son_i)$	failure rate of *i*th child

Appendix I

Reliability Block Diagram Computation Formulae

One of the modeling scenarios that can be implemented in RAM Commander's RBD module is K-out-of-N redundancy, with or without repair.

K-out-of-N Without Repair

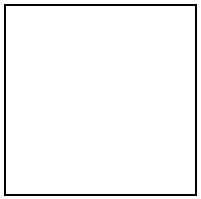
The formulas in the following table are used to compute MTTF and reliability for various redundant item loads and without item repair.

Source Data	Models	
Load of redundant items	MTTF	Reliability
100%	$\frac{1}{\lambda}\sum_{i=0}^{N-K}\frac{1}{K+i}$	$(N-K+1)\binom{N}{K-1}\sum_{i=0}^{N-K}\frac{(-1)^i\binom{N-K}{i}}{K+i}e^{-(K+i)\lambda t_0}$
0%	$\frac{N-K+1}{\lambda K}$	$e^{-K\lambda t_0}\sum_{i=0}^{N-K}\frac{(K\lambda t_0)^i}{i!}$
$0 < \nu \cdot 100\% \le 100\%$	$\frac{1}{\lambda}\sum_{i=0}^{N-K}\frac{1}{K+\nu i}$	$\frac{\prod_{i=0}^{N-K}(K+\nu i)}{\nu^{N-K}(N-K)!}\sum_{i=0}^{N-K}\frac{(-1)^i\binom{N-K}{i}}{K+\nu i}e^{-(K+\nu i)\lambda t_0}$

K-out-of-N With Repair $\gamma = \frac{\lambda}{\mu} = \frac{MTTR}{MTBF}$

The formulas in the following table are used to compute *MTBF* and reliability for various redundant item loads with item repair.

Source Data		Calculations Models		
Repair	Load of redundant items	MTBF (exact value)	Mission Reliability over time t_0 (approximate value)	Steady State Availability (approximate value)
Unre-stricted	100%	$\frac{1}{\mathrm{N}\lambda}\sum_{\mathrm{S}=0}^{N-K}\frac{\sum_{\mathrm{i}=0}^{\mathrm{S}}\binom{\mathrm{N}}{\mathrm{i}}\gamma^{i}}{\binom{N-1}{\mathrm{S}}\gamma^{S}}$	$\exp-\left\{N\lambda\, t_0 \,/\, \sum_{S=0}^{N-K}\frac{\sum_{i=0}^{S}\binom{N}{i}\gamma^{i}}{\binom{N-1}{S}\gamma^{S}}\right\}$	$1-\binom{\mathrm{N}}{\mathrm{N-K+1}}\gamma^{N-K+1}$
Re-stricted	100%	$\frac{1}{\lambda}\sum_{S=0}^{N-K}\sum_{\mathrm{i}=0}^{\mathrm{S}}\frac{1}{(i+1)!\binom{N-S+i}{i+1}\gamma^{i}}$	$\exp-\left\{\lambda\, t_0 \,/\, \sum_{S=0}^{N-K}\sum_{i=0}^{S}\frac{1}{(i+1)!\binom{N-S+i}{i+1}\gamma^{i}}\right\}$	$1-(N-K+1)!\binom{N}{N-K+1}\gamma^{N-K+1}$
Unre-stricted	0%	$\frac{1}{\mathrm{K}\lambda}\sum_{i=0}^{N-K}\binom{\mathrm{N-K+1}}{\mathrm{i+1}}\frac{i!}{(K\gamma)^{i}}$	$\exp-\left\{K\lambda\ t_0 \,/\, \sum_{i=0}^{N-K}\binom{N-K+1}{i+1}\frac{i!}{(K\gamma)^{i}}\right\}$	$1-\frac{(K\gamma)^{N-K+1}}{(N-K+1)!}$

K-out-of-N with Repair, 

Source Data		Calculations Models		
Repair	Load of redundant items	MTBF (exact value)	Mission Reliability over time t_0 (approximate value)	Steady State Availability (approximate value)
Re-stricted	0%	$\frac{1}{K\lambda}\frac{1-(K\lambda)^{N-K+1}[1+(N-K+1)(1-K\gamma)}{(K\gamma)^{N-K}(1-K\gamma)^2}$	$\exp-\left\{\frac{(K\gamma)^{N-K}(1-K\gamma)^2 K\lambda t_0}{1-(K\gamma)^{N-K+1}[1+(N-K+1)(1-K\gamma)]}\right\}$	$1-(K\gamma)^{N-K+1}$
Unre-stricted	$0<\nu\cdot 100\% \le 100\%$	$\frac{1}{\lambda}\sum_{s=0}^{N-K}\frac{s!\sum_{i=0}^{s}\frac{\gamma^i}{i!}\prod_{r=1}^{i}[K+(N-K+1-r)\nu]}{\gamma^s\prod_{r=1}^{s+1}[K+(N-K+1-r)\nu]}$	$\exp-\left\{\lambda t_0 / \sum_{S=0}^{N-K}\frac{s!\sum_{i=0}^{S}\frac{\gamma^i}{i!}\prod_{r=1}^{i}[K+(N-K+1-r)\nu]}{\gamma^S\prod_{r=1}^{S+1}[K+N-K+1-r)\nu]}\right\}$	$1-\frac{\gamma^{N-K+1}}{(N-K+1)!}\prod_{r=1}^{N-K+1}[K+(N-K+1-r)\nu]$
Re-stricted	$0<\nu\cdot 100\% \le 100\%$	$\frac{1}{\lambda}\sum_{s=0}^{N-K}\frac{\sum_{i=0}^{S}\gamma^i\prod_{r=1}^{i}[K+(N-K+1-r)\nu]}{\gamma^S\prod_{r=1}^{s+1}[K+(N-K+1-r)\nu]}$	$\exp-\left\{\lambda t_0 / \sum_{S=0}^{N-K}\frac{\sum_{i=0}^{S}\gamma^i\prod_{r=1}^{i}[K+(N-K+1-r)\nu]}{\gamma^S\prod_{r=1}^{S+1}[K+(N-K+1-r)\nu]}\right\}$	$1-\gamma^{N-K+1}\prod_{r=1}^{N-K+1}[K+(N-K+1-r)\nu]$

Reliability Distributions

The following table lists the probability distributions and associated reliability functions used in computing reliability.

Distribution	Reliability Function $R(t) = 1 - F(t)$	Probability Density Function $f(t)$	Parameters
Exponential	$e^{-\lambda t}$	$\lambda e^{-\lambda t}$	$\lambda = \frac{1}{MTBF} > 0$
Weibull	$e^{-(\frac{t}{a})^b}$	$ba^b t^{b-1} e^{-(\frac{t}{a})^b}$	a > 0; b > 0
Normal	$\int_t^\infty f(\tau)\, d\tau$	$\frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(t-\mu)}{2\sigma^2}}$	$-\infty < \mu < \infty$; $\sigma > 0$
Log normal	$\int_t^\infty f(\tau)\, d\tau$	$\frac{1}{\sigma t\sqrt{2\pi}} e^{\frac{-(\log t-\mu)^2}{2\sigma^2}}$	$-\infty < \mu < \infty$; $\sigma > 0$
Erlang	$e^{-\lambda t}\left[\sum_{i=0}^{\kappa-1} \frac{(\lambda t)^i}{i!}\right]$	$\frac{\lambda^\kappa t^{\kappa-1} e^{-\lambda t}}{(\kappa-1)!}$	$\lambda > 0$; κ - positive integer
Uniform	$\frac{b-t}{b-a}$	$\frac{1}{b-a}$ for $a \le t \le b$	$0 \le a < b$